would decide between the two views would be far from easy, but as I interpret Prof. Rutherford's letter, the results there given do not definitely disprove the view that the α particle is initially uncharged.

I recently directed attention ("Radio-activity," p. 181) to the importance of the fact that in certain well-established cases there appeared to be a simultaneous production of two positive charges in the disintegration of an electrically neutral atom. Thus in the disintegration of the emanation atom a positively charged α particle is expelled, and the residue of the atom—the matter causing the excited activity—is also positively charged, and is concentrated on the negative electrode in an electric field. In a recent paper by Bragg (*Phil. Mag.*, December, 1904, p. 721), the following sentence occurs:—"It is easy to see that even if the α particle is uncharged when it leaves the parent body, it must immediately become positive, since in traversing an atom it is just as likely to lose one of its own electrons as to take one away from the atom traversed." As I am unaware that this consequence has received the attention it deserves, perhaps I may be allowed to direct attention to its bearing on the present question. There is a fundamental distinction between the ionisation of the atom of a gas molecule by radiant *electrons* or β particles, and radiant *atoms* or α particles. For in the latter case, if the atom struck suffers ionisation, the radiant atom is just as likely to be ionised in the process also. The ionisation of a neutral atom consists in the detachment from it of an electron which forms the negative ion, the atom thereby becoming positively charged and forming the negative ion. Hence the radiant α particle, if uncharged initially, will become positively charged on collision with the atoms of the gas or other obstacle in its path, and at the same time will lose an electron. The "slow-moving electrons present with the α particles," which Rutherford describes as "emitted from the plates," may therefore in reality be derived from the α particles themselves in the act of becoming positively charged. The fact that they, unless deflected by a magnetic field, exactly neutralise the charge carried by the α particles seems to point in the same direction.

In further support of the view that the positive charges on both the radiant particle and the residue of the atom after disintegration are derived by collision with the gas molecules, Prof. Rutherford's results on the distribution of the excited activity in an electric field at low pressure may be cited (Rutherford, "Radio-activity," p. 282). If the excited-activity-matter particle gains its positive charge in its recoil by collision with the gas molecules, it is to be expected that at low pressures it will not become charged, and will not, therefore, be concentrated on the negative electrode, as is, in fact, the case.

FREDERICK SODDY.

The Pressure of Radiation.

THE success of Lebedeff and Nichols and Hull in recognising and measuring the pressure of radiation has aroused much interest in radiation pressure generally, real or apparent. It has some interesting and sometimes somewhat difficult theoretical aspects. In the first place, if the ether is really absolutely at rest (this rigidity is a very difficult idea), the moving force on it has no activity, and its time integral $V\mathbf{DB}$ can only be called momentum out of compliment. The force becomes active in a moving ether, with interesting consequences not now under examination. The present question is rather how to interpret the pressure of radiation on the assumption of a fixed ether, in the measure of its effects on matter which is either fixed or moving through the ether.

The following is striking in what it proves. Let plane radiation fall flush upon a perfect reflector moving in the same direction at speed u, a case considered by Larmor. Let the energy density $p=p_1+p_2$, the incident being p_1, the reflected p_2. Assume, which seems reasonable at first, that p_3, the pressure in the reflector, is zero, then the moving force $p_1+p_2-p_3$ reduces to p_1+p_2. Therefore

$$p_1(v-u)-p_2(v+u)=(p_1+p_2)u, \qquad (1)$$

because the left side is the rate of loss of energy from the waves, and the right side the activity of the force on the reflector. So

$$\frac{p_2}{p_1}=\frac{1-2u/v}{1+2u/v}=s^2, \text{ say}, \qquad (2)$$

and $s=H_2/H_1$ is the ratio of magnetic forces in the electromagnetic case. Now (2) asserts that the reflected wave gets smaller as the mirror goes faster, and vanishes when $u=\frac{1}{2}v$. Or if the mirror be pushed against the radiation, the reflected wave gets stronger, and the resisting force stronger until $u=-\frac{1}{2}v$, when it is infinite. The mirror could not be pushed against the radiation faster than $\frac{1}{2}v$.

An immediate objection is that when u has risen to $\frac{1}{2}v$, if it be maintained at that speed it acts like a perfect absorber to the incident energy. Moreover, since there is the pressure p_1 left, why should it not accelerate the mirror? But, if it does, p_2 becomes negative, and s becomes imaginary. Considered mechanically only, say by $F=m\dot{u}$, the motion of m is quite determinate when $u>\frac{1}{2}v$, up to v, in fact. But electromagnetically it means that the energy in the reflected wave is negative. Now although there is nothing to object to quantitatively in a continuous transition from a Maxwellian stress consisting of a tension along an axis combined with equal lateral pressure, to its negative, a pressure along the axis with equal lateral tension, still the negativity of the energy in the reflected wave causes difficulty. The stress for both the electric and magnetic energy becomes of the gravitational type. That is, like imaginary electrifications attract, and unlike repel, or matter is imaginary electrification in this comparison. The moving forces and energies are real. But let a real charge and an unreal one co-exist, the energy density becomes imaginary. That is out of all reason in a real universe.

We should, I think, regard (2) as a demonstration that (1) is untrue, in that $(p_1+p_2)u$ is not the activity of the force on the mirror, although p_1+p_2 may be actually the pressure of the radiation. In fact, in the electromagnetic case, the variation of p constitutes a force on the ether itself. We must find the force on the mirror in another way. Let radiation fall flush upon the plane surface of a dielectric, which call glass, moving the same way at constant speed u, and let the circuital equations in the glass be

$$-dH/dx=c\dot{E}+\partial I/\partial t, \quad -dE/dx=\dot{B}=\mu\dot{H}\,; \qquad (3)$$

that is, the same as for the ether, with the addition of the electric current of polarisation $\partial I/\partial t$. The reference space is the fixed ether, and $\partial/\partial t$ is the moving time differentiator. Now if the relation between I and E is such as to permit of an undistorted plane wave, we shall have

$$\underset{\text{(incident)}}{E_1=\mu vH_1}, \quad \underset{\text{(reflected)}}{E_2=-\mu vH_2}, \quad \underset{\text{(transmitted)}}{E_3=\mu wH_3}, \qquad (4)$$

if v is the speed in the ether, and w the wave speed referred to the ether in the glass. This w is a function of u. Also, the boundary conditions,

$$E_1+E_2=E_3, \quad H_1+H_2=H_3, \qquad (5)$$

combined with (4), give

$$H_2/H_1=(v-w)/(v+w), \quad H_3/H_1=2v/(v+w). \qquad (6)$$

An incident pulse of unit depth is stretched to depth $(1-u/v)^{-1}$ in the act of reflection; the reflected pulse is of depth $(v+u)(v-u)^{-1}$, and the transmitted pulse of depth $(w-u)(v-u)^{-1}$.

The rate of loss of energy from the waves in the process of reflection is

$$p_1(v-u)-p_2(v+u)-p_3(w-u), \qquad (7)$$

where the p's are the energy densities. But, by the above,

$$p_1v=p_2v+p_3w\,; \qquad (8)$$

therefore the rate of loss of energy is

$$(p_3-p_1-p_2)u, \qquad (9)$$

and the moving force on the mirror is

$$F=p_3-p_1-p_2. \qquad (10)$$

This is, in its expression, exactly the *negative* of the previous pressure difference. It is in the direction of the rise of energy density. Its amount is

$$F=2\mu H_1H_2=2p_1(v-w)/(v+w)=\tfrac{1}{2}\mu H_3^2-\tfrac{1}{2}cE_3^2=U_0. \qquad (11)$$

The first form in terms of H_1, H_2 is useful. The second is in terms of the wave speeds. The third is in terms of the ethereal energy inside the glass. All these come out of the ratios H_2/H_1, &c. Now the electric energy equals the magnetic energy in the transmitted wave. Consequently U_0 means the energy of the polarisation I. And the activity is U_0u, the convective flux of energy.

These properties are true for various relations between I and E. The first approximation is $I = c_1 E$. The second, introduced by Lorentz, is $I = c_1(E - uB)$, that is, the polarisation is proportional to the moving force on a moving ion. Other forms allowing of undistorted pulse propagation may be proposed. All give special relations between w and u. In Lorentz's case,

$$U_0 = \tfrac{1}{2} c_1 E_3^2 (1 - u/w)^2. \qquad (12)$$

To pass to perfect reflection, reduce w to u, its least value. U_0 does not vanish, but has the value given by (10), (11) still, with $w = u$. But the transmitted wave is reduced to a surface film, moving with the glass. The moving force on the glass is now

$$F = 2p_1 (w - u)/(v + u), \qquad (13)$$

and finally, if $u = 0$, $F = 2p_1$.

Here we come right back to the pressure of radiation. It does measure the force on the glass when at rest, when it reflects perfectly, and it looks as if (13) were merely the form $p_1 + p_2$ a little modified by the motion. But appearances are very deceitful here, for (10) above is the proper formula.

As regards the distribution of F. With an actual transmitted wave consisting of a pulse of uniform intensity all through, F is entirely at the wave front. So, with total reflection, it is just under the surface of the glass. Again, if E_3 varies continuously in the transmitted wave, F is distributed continuously, to the amount $B(\partial I/\partial t)$ per unit volume. What F means in (11) now is the total of this volume force, *i.e.* the integral from the surface up to the wave front, expressed in terms of the momentary surface state.

After a pulse has left the surface there is an equal opposite force at its back, so there is no further loss of energy or moving force on the glass. The obscurities and apparent contradictions arise from the assumption that the ether is quite motionless. If we treat the matter more comprehensively, and seek the forces in a moving ether, with moving polarisable matter in it as well, if this is a complication one way it is a simplification in another, viz. in the ideas concerned. There is harmony produced with the stress theory. To illustrate, $(\partial/\partial t)\mathrm{V}\mathbf{DB}$ is the moving force per unit volume when the ether and polarised matter have a common motion, $\mathbf{D}$ and $\mathbf{B}$ being the complete displacement and induction. (The variation of $\mathbf{u}$ is ignored here.) But if we stop the ether, a part of this force becomes inactive. If the matter is unmagnetisable, the only active part is that containing the polarisation current, for that is carried along.

Besides this electromagnetic force, there is also a force due to a pressure of amount U_0. But it does not alter the reckoning of the moving force on the glass, because the pressure acts equally and oppositely at the front and back of a pulse.

Some other illustrations of the curious action between electromagnetic radiation and matter can be given. For example, two oppositely moving plane pulses inside moving glass. Say $E_1 = \mu w_1 H_1$ one way with the glass, and $E_2 = -\mu w_2 H_2$ against the glass. If $H_1 = -H_2$, work is done upon the glass when they cross, ceasing the moment they coincide, so that the energy of the momentary electric field is less than the wave-energy. On separating, the loss is restored. If, on the other hand, $E_1 = -E_2$, work is done by the glass on the waves when uniting, so that the momentary magnetic energy, together with the polarisation energy, is greater than the wave energy. In this second case, too, it is noteworthy that the solitary waves are of unequal energy, whereas they are equal in the first case. But details must be omitted, as this communication is perhaps already too long.

OLIVER HEAVISIDE.

February 21.

Secondary Röntgen Radiation.

IN a paper read before the Royal Society on February 16, I described experiments demonstrating the partial polarisation of Röntgen radiation proceeding from an X-ray bulb, and at the same time verifying the theory previously given of the emission of secondary X-rays from gases and light solids subject to Röntgen radiation.

Later experiments have shown that beams of X-radiation may be produced exhibiting a greater amount of polarisation than there was evidence of in the original experiments. This discovery has proved useful in the investigation of secondary radiation proceeding from solids.

It has been found that while the intensity of secondary radiation from light substances varies considerably in different directions owing to the partial polarisation of the primary radiation, the amount of this variation diminishes with an increase in the atomic weight of the radiator, and ultimately is inappreciable. The radiations from air, carbon, paper, aluminium, and sulphur vary in intensity in different directions by a considerable amount. From calcium the variation is much less, while from iron, copper, zinc, and lead it is inappreciable. This must be connected with the fact that the radiation from light substances differs in character only very slightly from the primary, while the heavier substances emit radiations differing more from the primary producing them. The radiation from the heavier metals was found not to consist of an easily absorbed radiation superposed on a radiation such as proceeds from light substances, and of intensity given by the law found for that from light substances, but is as a completely transformed radiation. This is strong evidence that the freedom of motion of the electrons which permits what may be called a simple scattering in substances of lower atomic weight is interfered with in the heavier atoms, for we find from them a more absorbable radiation *in place of, not simply superposed on,* a more purely scattered radiation.

With this change in character, the polarisation effect disappears. No special absorption of the radiation proceeding from a substance by plates of the same substance has been observed.

A considerable variation in the penetrating power of the primary radiation incident on heavy substances is accompanied by a smaller change in that of the secondary (measured by change of absorbability).

Radiation from compounds appears to be merely a mixture of the radiations which proceed from the separate elements in the compound, both the absorbability and polarisation effects being what would be given by such mixtures. Atomic weight, not molecular weight or density, thus seems to govern the character of the radiation produced by a given primary.

These results may be accounted for by considering the electrons constituting the atoms as the radiators. In light atoms the electrons are far enough apart, and have sufficient freedom to move almost entirely independently of one another, under the influence of the primary pulses, consequently to emit a secondary radiation similar to the primary, but the intensity of which depends on the direction of propagation with regard to that of electric displacement in the primary beam. In heavier atoms considerable inter-electronic forces are probably brought into play by small displacements, and the resultant acceleration of motion of an electron is then not in the direction of electric displacement of the primary beam, and evidence of polarisation of that beam vanishes. Also there ceases to be a simple connection between the time for which the electron is accelerated and that of passage of the primary pulse.

In atoms of greater weight we would expect appreciable inter-electronic forces to be called into play sooner, and to attain a much greater intensity than in lighter atoms.

The precise connection between the atomic weight of the radiator and the absorbability of the radiation is being investigated.

CHARLES G. BARKLA.

University of Liverpool, March 1.

Dates of Publication of Scientific Books.

I HAVE just bought a copy of "A Treatise on Slate and Slate Quarrying, Scientific, Practical, and Commercial," by D. C. Davies, F.G.S., fourth edition, dated 1899 (Crosby Lockwood and Son).

To my astonishment, I find no statistics of later date in it than 1876, *e.g.* p. 33, statistics of 1872 and 1873, p. 58, list of quarries in 1873, p. 59, production in 1876, p. 64, production last year (1876), p. 170, prices of slates in London last year (1876).

As the Home Office publishes annually a general report and statistics of mines and quarries, and also a list of mines and quarries, there is no excuse for the book being so out of date in its statistics.

B. HOBSON.

The Owens College, Manchester, February 21.